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IMPROVING CONSTRUCTION PROJECTS AND REDUCING RISK BY USING ARTIFICIAL INTELLIGENCE

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Abstract: Architectural, engineering and construction (AEC) industry has large amounts of data, the analysis of which can predict risks such as project delays, project budget overruns, low resource use efficiency, environmental damage, reduced safety, and the like. Research has shown that 98% of construction projects are realized with the contracted budget and deadline exceeded. This paper aims to show the significant potential and possibilities of applying artificial intelligence (AI) in the AEC industry, pointing out the benefits and obstacles faced by the AEC industry during the implementation of AI. The benefits of applying AI in the AEC industry relate to increasing efficiency, reducing costs, increasing productivity, increasing safety, better planning and providing timely and accurate information. The key obstacles that hinder the implementation of AI in practice are high implementation costs, incomplete data, job loss due to automation, mistrust of AI technology, cyber vulnerability, and lack of understanding field of AI.

Keywords: AEC industry, artificial intelligence, construction technology, AI opportunities.

Introduction

The Architecture, Engineering and Construction industry (AEC) is one of the industries that is slowest to use and adopt the capabilities of modern analytical methods of artificial intelligence to predict factors that could have a negative impact on the project (Egwin et al., 2021).

Artificial intelligence (AI) has significant potential to contribute to the AEC industry throughout the project's lifecycle from various aspects such as project safety, cost, timeline and resource management. A key benefit of applying artificial intelligence in construction is automating human processes, making processes more efficient while reducing potential human errors. The benefits of applying AI in the AEC industry relate to solving or reducing problems that are almost inevitable in a project, from various aspects of a construction project.

The problem of schedule and budget overruns in the construction industry is a global problem (Sambasivan et al., 2007), and almost 98% of construction projects are overscheduled and over budget (McKinsey, 2015). The reasons that cause these overruns are inadequate project planning and management, lack of communication between project participants, ineffective material management, equipment failure, project solution variations, ineffective resource management, and the use of outdated tools and technologies (Tariq, 2023).

With the development of artificial intelligence, it is necessary to pay more attention to the protection of data and the application of controls to protect against cyber attacks. Cyber attacks are increasingly common in the construction industry, containing large amounts of confidential data about projects and employees (Beckage and Parziale, 2021). Cyberattacks are often carried out for profit, as in the case of the Canadian company Bird Construction in 2019 and the French company Bouygues in 2020 (Haynes, 2023). In both cases, the cyber attackers demanded a ransom by locking and encrypt-ing confidential data from the project. This affected the delays in the projects of these companies. Cyber attacks often cause a chain reaction, triggering a series of risks in the company.

A review of the existing literature found that the application of AI is possible in almost all phases of a construction project and significantly affects the improvement of the overall quality and delivery of the project.

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Application of Artificial Intelligence in the AEC Industry

By applying artificial intelligence in construction projects and processes, it is possible to reduce the risk in different phases of the construction project. The risks that are most often realized during the project are exceeding the estimated budget and the deadline for the project implementation, violation of safety and health at work, and excessive consumption of resources during the construction and maintenance of facilities. The authors developed models and algorithms based on AI, and the results positively impacted the projects.

Cost

Artificial intelligence can improve the accuracy of project cost estimates and thus reduce economic risks. As traditional cost estimation is subject to human error, AI-based models automatically analyze large amounts of data and thus provide more accurate project cost estimates. Elfahham, 2019 evaluated the construction cost index (CCI) with the help of predictive models based on artificial intelligence. This index is helpful when predicting costs on future projects and reducing the risk associated with the inflation rate.

Integrating drones and artificial intelligence for construction inspection and data processing significantly reduces costs by eliminating the need for inspection vehicles, platforms and cranes for inspection at height and hiring more trained operators. Also, by regularly and reliably inspecting the structure, maintenance costs are reduced if the damage is detected in time (Nwaogu et al., 2023).

Kim et al., 2004 performed a comparison of three models for estimating total project costs based on multiple regression analysis (MRA), artificial neural networks (ANN) and case-based reasoning (CBR). The database consisted of 530 projects of built residential buildings. A model based on neural networks gave the most accurate cost estimate, whose average absolute error was 2.97%. The average absolute estimation error of the MLR model was 6.95%, and that of the CBR model was 4.81%.

Deadline

Extending the deadline for project implementation is one of the most frequent challenges faced by the construction industry. Egwim et al., 2021 developed a multi-layer Ensemble Machine Learning Algorithm (EMLA) to improve the predictive power compared to applying only one algorithm when predicting the extension of deadlines in construction projects. Twenty-four input data were used, such as project scope, equipment failure, inflation or sudden increase in the price of raw materials, the effectiveness of communications, weather conditions, design solution of construction, decision making, cash flow during the project, procurement of materials, political influences, quality of project control and the second.

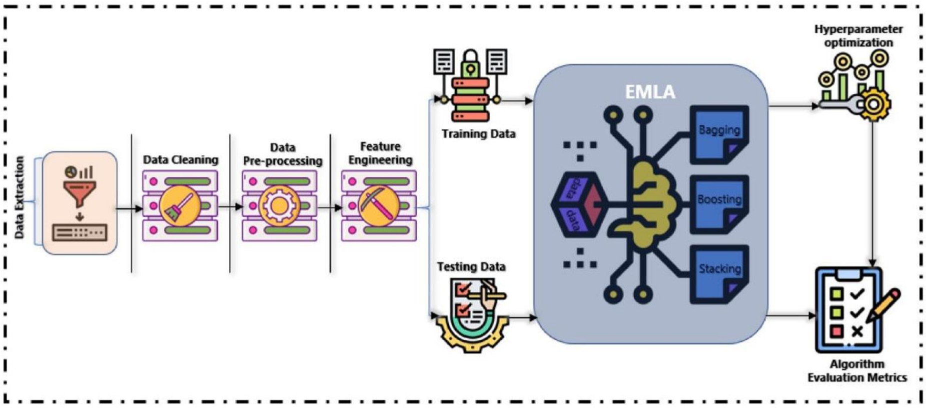

Figure 1. Methodological Approach to the Development of the EMLA assessment model (Egwim et al., 2021)

Figure 1. shows the methodological approach to developing the EMLA prediction model. This approach involves collecting, processing and preparing data for model development, then model development. Model development refers to training and testing models based on machine learning, setting hyperparameters and evaluation, i.e. measuring model accuracy. The analysis showed that EMLA algorithms provide better results than using only one machine learning algorithm.

Quality of communication

Project results, productivity and efficiency of activities depend on the level of communication quality. Rahimain et al., 2022 developed a model based on artificial neural networks to predict the quality of mutual communication among project employees. The predictive model connects interpersonal skills with communication, which can indicate conflicts before they escalate, and at the same time, direct construction managers to form interpersonal skills training. The database based on which the prediction of the quality of communication was made consisted of 180 responses from experts from the construction industry. The survey was formed so that experts formed opinions about the level of communication quality based on leadership style, listening, team building and clarifying expectations. The achieved accuracy of model prediction is up to 80%.

Safety and Health at Work

Safety and health at work are necessary conditions for the realization of a construction project. Baker et al., 2020 developed predictive models based on machine learning to estimate incident type, injury type, body part injured and injury severity. Over 80 attributes were defined with the help of the Natural Language Processing NLP method from injury reports, which include means and methods of construction as well as environmental conditions. Prediction models based on the following algorithms were compared: CART, Random Forest, KSGBoost, and Linear SVM. The SVM model proved to be the best predictive model.

Project planning and monitoring

Lin and Golparvar-Fard, 2017 proposed a project management system that aims to compare the visual data of the current state of the construction site by advanced mapping in 4D with the BIM model representing the planned facility. The authors use predictive analytics and real-time information from the construction site to predict construction progress, highlight potential site-specific issues, and support collaborative decision-making that eliminates the causes of loss.

Generative design, projecting

Algorithms for generating project solutions are a great help to designers because, in a short time, they generate a large number of project solutions and can compare from different aspects. Zhang et al., 2021 developed a parametric generative algorithm that combines artificial intelligence and green building design principles to optimize the performance of residential buildings in the early stages. The generative algorithm was formed using Rhino/Grasshopper and Python tools. Alsakka et al., 2023 developed an approach based on generative design concepts, generic algorithms and the Lagrangian Multiplier Method to design reinforced concrete elements with an optimized shape to achieve material savings and reduce CO_2 emissions. Figure 2 shows the difference between a classically designed cantilever beam and one optimized from the aspect of material installation.

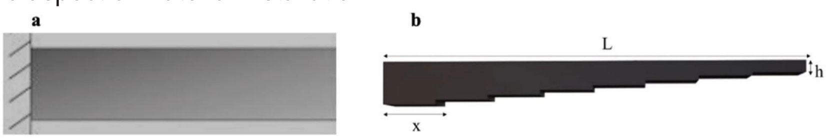

Figure 2. Traditionally designed beam (a) and optimized (b) (Alsakka et al., 2023)

Optimization of building maintenance

By processing the data collected from smart buildings with the help of artificial intelligence, it is possible to optimize building maintenance from energy efficiency. By managing the temperature, lighting and CO_2 concentration in the building, energy consumption and the comfort of the living space are optimized. Visual systems and sensors can improve the safety of residents in buildings, especially during fire detection Baduge et al., 2022.

Improvement in construction

Digital Twin Construction represents a comprehensive construction method that provides the possibility of closing control loops where management decisions are made based on reliable, accurate, complete and timely information. Information is obtained through continuous monitoring of construction site status and data analytics to assess possible outcomes of alternative projects and planned decisions Sacks et al., 2020.

Nwaogu et al., 2023 investigated the integrated application of drones and artificial intelligence. Drones greatly facilitate the visual inspection of construction and access to inaccessible places, while the application of artificial intelligence facilitates the collection and processing of data.

Kumar et al., 2016 considered how the construction work's automation and robotisation affect the project. The construction activities covered in the study are preparing reinforcing mesh, finishing works on the interior and floors, quality inspection, using drones to transfer cargo and sensors to detect proximity. The study results show that with automation and the use of robots, it is possible to shorten the time of performing activities by up to 57.85% and reduce total costs by 51.67% while increasing quality. Costs caused by rework and waste are reduced by 66.76%.

Advantages and limitations of the application of subfields of artificial intelligence

As AI is widely used in the construction industry and almost all phases of the construction project, it is necessary to investigate the level of resistance and the benefits of its application. It is very important to explore further strategies to overcome the barriers and justify the investment of monetary resources and efforts to apply AI in AEC. Table 1 shows the advantages and obstacles when implementing the subfield of artificial intelligence in different construction project phases.

Table 1. Advantages and limitations of the application AI in AEC (Abioye et al., 2021)

The field of artificial intelligence	Application advantages	Limitations of application
Machine learning	Relevant predictive and prescriptive insights	Incomplete data
	Increasing efficiency	Learning from streaming data
	Reduction of costs	Working with high-dimensional data
	Improving security	Model adaptability
	More efficient use of resources	Distributed computing
	Reduction of project errors and omissions	
Computer Vision	Faster checks and monitoring	A complete understanding of the entire scene
	Higher precision, reliability and transparency	Recognition of equipment or work activity
	Higher cost efficiency	Improvement of tracking accuracy and effective visualization of tracking results
	Increased productivity	
	Increased security	
Automated Planning and Scheduling	Cost reduction through process improvement, better logistics	High cost of implementation
	Increasing productivity	It can be complex
	Reduction of planning effort	Representing knowledge necessary for models, monitoring issues, integration, etc.
	Simplification of monitoring and control	
	Optimal plans and schedule	
Robotics	Increased security	High initial investment
	Increased productivity	Potential job loss during automation
	Improved quality	Unstructured work environment
	Better reliability and accuracy	
	Faster and more consistent than humans	
Knowledge-based systems	Easy access to relevant information	Intellectual property protection and security issues
	Simple data update	Problems of acquiring knowledge
	Ability to explain the reason for the adopted solution	Problems with knowledge validation
	Consistency and availability	
	Ability to work with incomplete information	
	Pure logic	
Natural language processing	Increased productivity	Adequate representation of fragmented, extended and erroneous language
	Cost efficiency	Speech recognition issues include construction site noise, homonyms, accent variability, etc.
	Time efficiency	Privacy and data security issues
	Improved communication between stakeholders	
Optimization	Increased productivity through process optimization	It requires significant computing power
	Increased efficiency	A question of scalability
	Cost and time savings	

Distrust as an obstacle to the application of AI in AEC

The application of artificial intelligence in the AEC industry is growing, but research into the relia-bility of this technology is important. In their work, Emaminejad and Akhavian, 2022 analyze the relia-bility and safety of the application of artificial intelligence and robotics in the AEC industry by analyzing 584 scientific papers published in the last two decades. It was found that simpler systems that are ex-plainable and transparent have more reliable results and that AI systems must be protected from un-authorized actions to avoid accidents due to the operation of heavy construction robots. As people have certain expectations regarding the performance of AI applications, autonomous systems must show timely failures or errors in processes to maintain trust in such systems.

An et al., 2021 argue that the lack of a comprehensive understanding of the factors that lead to

insufficient reliability, uncertainty, and the application of artificial intelligence in the AEC industry limits the effectiveness of the application. Reasons that lead to insufficient reliability are limited data sets, generalization, subjectivity in initial assumptions, and subjectivity in algorithm structures. The author has generated a framework for which he proposes steps to improve the application of artificial intelligence in the AEC industry. The framework includes three basic elements: ITC (Information and Communication Technology) infrastructure for data digitization, RIBA (Royal Institute of British Architects) work plan that defines the required data sets, and AI algorithms' application to defined data sets. After that, the model's performance is evaluated based on the obtained results. If the results are satisfactory, the process ends. Otherwise, the previously mentioned reasons that lead to insufficient reliability are analyzed, and guidelines are proposed for reducing uncertainty. The model's performance is re-evaluated, and this process is repeated until satisfactory results are obtained. Figure 3. shows the framework for improving the application of artificial intelligence in the construction industry.

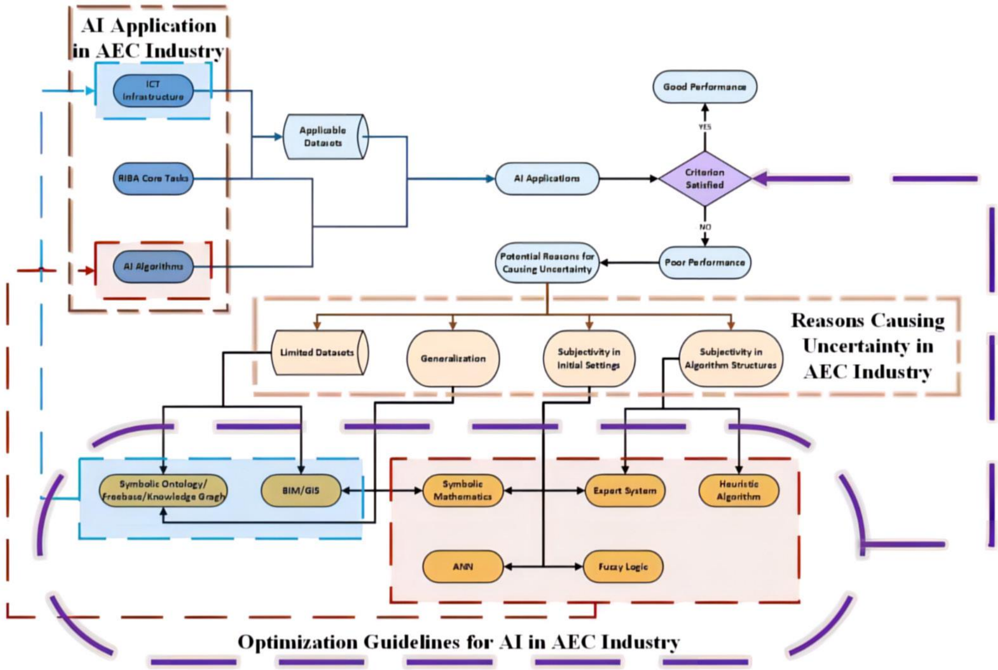

Figure 3. Framework for advancing the application of AI in the AEC industry (An et al., 2021)

Revolutionary solutions provided by artificial intelligence must be adopted cautiously due to cybersecurity issues. Garcia de Soto et al, 2022 conducted a survey to understand AEC industry experts' awareness of cybersecurity issues. The results were analyzed to identify shortcomings and make suggestions for improving cyber security in practice. Cyber attacks to achieve profit or other goals can lead to the disruption of processes and changes in information that can cause material damage or loss of human life. Survey results show that 84% of respondents are concerned about cyber security. However, only 39% said their company has a cyber security plan, indicating that cyber security is not a top priority for companies. A better understanding of threats and vulnerabilities is necessary to create and follow adequate guidelines for defence against cyberattacks. There is a lack of cybersecurity frameworks specific to the construction industry to help develop strategy, adjust budgets, and make cybersecurity a higher priority. Governments have no cybersecurity requirements for contractors to ensure a safer work environment.

Conclusions

The application of different sub-fields of artificial intelligence in the field of the AEC industry can significantly improve the performance of the entire project through different phases. By analyzing the changing market and economic factors that affect costs, it is possible to obtain information that could predict economic instability. With the help of artificial intelligence, it is possible to understand the scope of the project better and identify missing information, as well as identify conflicts on the project, thereby ensuring the possibility of determining more precise offers for the entire project, deadlines for implementation, as well as the risk of injuries. Implementing AI in the planning and monitoring phases of

building construction ensures an increase in safety at work and an increase in the quality of communication between collaborators on projects. Generative algorithms optimize the use of resources throughout the entire life cycle of the building. Some of the obstacles that significantly slow down and make it difficult to realize the full potential of AI application in AEC are related to mistrust due to a lack of understanding of the field of AI, fear of job loss due to process automation, limited data sets that lead to wrong generalization as well as higher initial financial investments. Applying AI in construction can improve various parameters such as time, cost and quality.

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Conflict of interests
We have no known conflictof interest to disclose

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